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	Subsystem/Office Calorimeter Subsystem	

Document Title

Performance of EM CsI(Tl) Crystals

CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes
1		Initial Release

1 Introduction

This document describes tests of the performance of CsI(Tl) crystals manufactured by Amcrys for the GLAST Engineering Model calorimeter. We measured the optical performance – light yield and light taper – and we measured the dimensions of the EM crystals for comparison with optical and mechanical specifications. These requirements are given in CAL CsI Crystal Performance Specification (document LAT-SS-00820), and CAL CsI Crystal Specfication (document LAT-SS-00095).

We conclude that – after some rework – the crystals met the requirements we specified for the EM Calorimeter. The initial failure to meet specifications and the subsequent, successful rework were caused by our having modified the requirements after the EM crystal manufacturing had begun. We therefore have every expectation that the FM crystal build will be successful.

2 Crystal preparation

The EM CsI(Tl) crystals were manufactured by Amcrys-H, the commercial arm of the Institute for Single Crystals in Kharkov, Ukraine. After their manufacture, they were sent to Kalmar University, Sweden, for verification (and mechanical rework – see below), prior to being forwarded to NRL or CEA/Saclay for assembly into Crystal Detector Elements.

The crystals were machined to dimension (nominally 333 mm $\times$ 26.7 mm $\times$ 19.9 mm, with a chamfer on the four long edges) and polished on all faces. The scintillation light was tapered (i.e. made to decrease with increasing distance

Figure 1: EM CsI crystals wrapped in Tyvek, aluminum foil, and vacuum sealed. Arrival at NRL.

Figure 2: Bare CsI(Tl) crystal

from one end face) by roughening the long surfaces (typically two of the four long surfaces). Optical and dimensional measurements were made at the factory. The crystals were wrapped in an optical sleeve of Tyvek and aluminum foil, vacuum bagged, and shipped in wooden crates. A set of EM crystals in their shipping wraps is shown in Figure 1. A bare CsI(Tl) crystal is shown in Figure 2.

While these crystals were being manufactured, a thorough study of the build-up of dimensional tolerances revealed that the crystals had to be shortened slightly and the chamfers on the crystal edges had to be enlarged. We therefore revised the crystal specification and returned the crystals to the manufacturer for reworking. Amcrys shortened the crystals to the new nominal length (326 mm) by milling 7 mm from one end of the crystal. The new crystal end face was cleaned and very lightly polished, which left a surface whose roughness was defined primarily by the milling tool. The crystals were then sent to Kalmar, where the chamfers were reworked. Because of schedule constraints, no optical measurements were made of the reworked crystals in the Ukraine or Sweden, and we waived the optical requirements for reworked crystals that had originally satisfied optical specifications. Amcrys would make no guarantees of the optical performance after remachining, and our expectation was that the light yields might suffer only modest change, while the light tapers might be more significantly changed.

Upon arrival of the crystals at NRL, we performed a visual inspection for identifying features or serious flaws, and we passed each crystal through a go / no-go gauge set to the maximum of each dimension. We then measured the optical properties of each crystal.

3 Optical properties

We tested the optical properties of the EM crystals – the light yield and light taper – and compared the performance to the relevant specifications. The optical tests were performed at Amcrys and at NRL with a Crystal Optical Test Station (XOTS). The optical requirements are specified from the centroid or resolution – as appropriate – of the 511 keV gamma-ray line from a collimated ^{22}Na in the XOTS. The data acquisition procedure is given in (### ref ###). We summarize it here in brief. A CsI(Tl) crystal in its factory wrapper is mounted between two red-sensitive photomultiplier tubes (PMTs), and the PMTs are brought into dry contact with the full end faces of the crystal. A collimated ^{22}Na source is translated to 11 positions along the length of the crystal, and spectra in each PMT are accumulated for several minutes at each location. To ensure consistency of test results, the spectra are modeled and analyzed with a standard analysis package (### ref ###) written at NRL and distributed to CEA/Saclay, Kalmar and Amcrys.

Results of these optical tests on the EM crystals are detailed in the following sections.

3.1 Light yield

The EM crystal specification requires that the 511 keV gamma-ray line measured at the two ends of a crystal have a full-width-half-maximum (FWHM) of less than or equal to 13% with the source at each of the 11 fiducial positions.

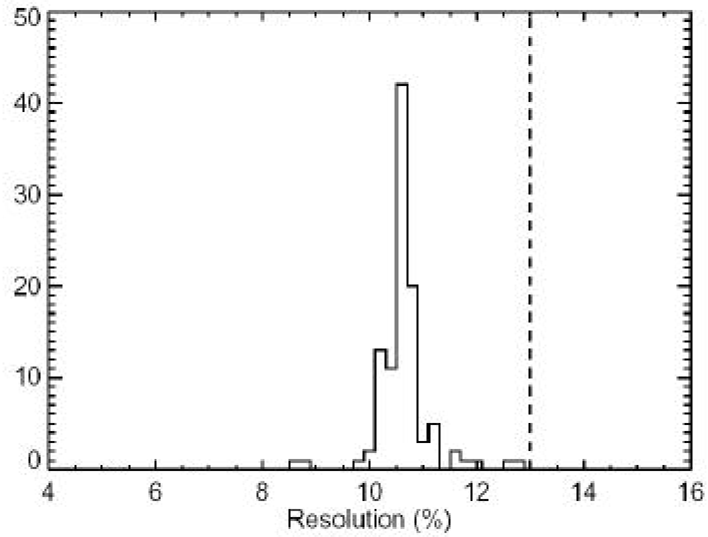

Figure 3: Resolution (FWHM) of 511 keV line from ^{22}Na in EM crystals. Dashed line indicates requirement, FWHM < 13%.

3.2 Light yield uniformity

The EM crystal specification requires that the relative light yields among crystals be equal to within 10%. Note that we

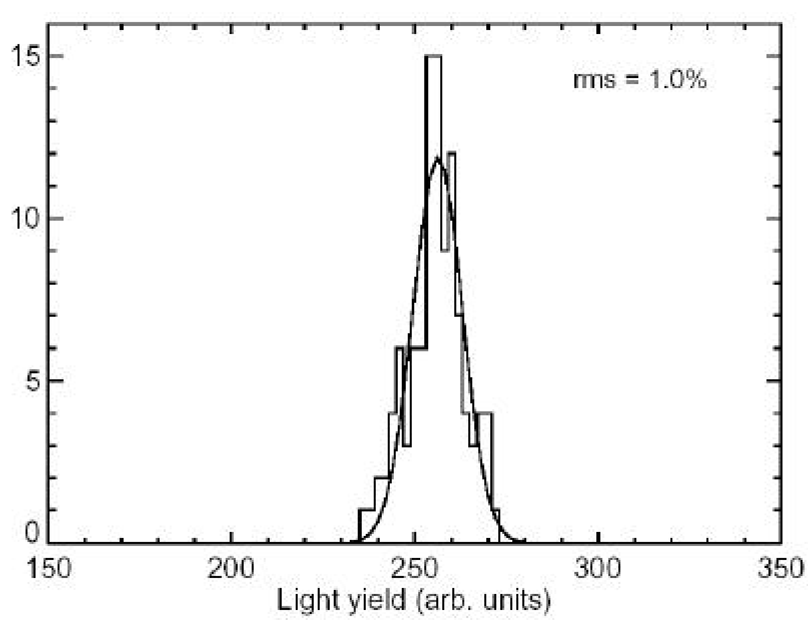

Figure 4: Distribution of light yields in EM crystals as represented by centroid of 511 keV line in Crystal Optical Testing Station measurements.

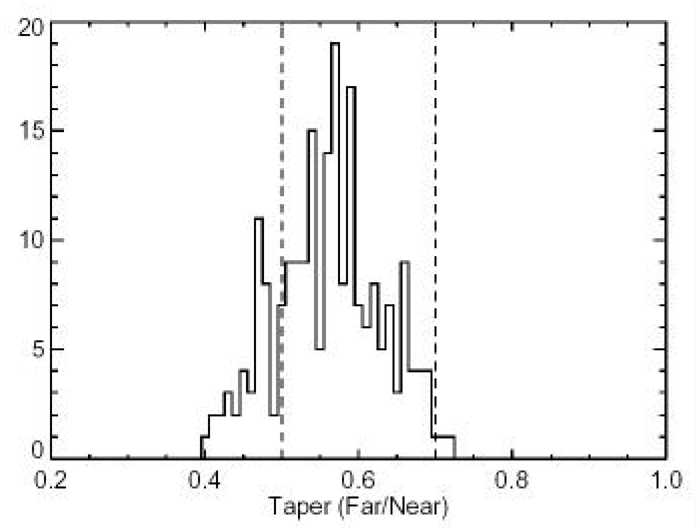

Figure 5: Light taper in EM crystals. Taper is expressed as ratio of signal 2 cm from the far end of the crystal to the signal 2 cm from the near of the crystal (LAT-SS-00820). Dashed lines indicate requirement.

do not require and make no attempt to measure the absolute light yield of crystals because the XOTS readout is quite different from the EM readout: the XOTS uses photomultiplier tubes in direct contact with the full end face of the crystal, while the EM readout is dual PIN photodiodes bonded with a silicone optical encapsulant. Instead, to test for consistency, we measured the centroid of the 511 keV line from ^{22}Na in each EM crystal with the XOTS.

The FM CDE specification requires scintillation light yields of >7000 e/MeV in the big PIN and >1100 e/MeV in the small PIN. To test whether the SE window is sufficiently transparent to CsI(Tl) scintillation light, we measured the light yield in six DPDs bonded to three EM CDEs at Swales. As part of the verification of the EM CDE build, we placed all EM CDEs in a muon telescope with calibrated electronic gain. From the amplitude of the muon peak and the known most-probable energy deposition of sea-level muons, we calculated the light yield of each big and small PIN diode of each CDE.

4 Light taper

Figure 5 displays the distribution of measured light tapers for the EM crystals. The EM crystals were manufactured to the LAT-SS-00095-5 taper specification which was measured with Tyvek wraps. The increased light yield of the VM2000 wrap also diminishes the light taper. That is why so many crystals in Figure 5 appear below the minimum taper specification. For flight crystals we have modified the taper specification to recover the specified taper when wrapped in VM2000 – the flight optical wrap.

Table 1: Crystal dimension specification, from LAT-SS-00820.

Parameter	**Maximum Value (mm) at 20 - 25 °C**	**Minimum Value (mm) at 20 - 25 °C**
Crystal Length	326.00	325.40
Crystal Height	19.90	19.50
Crystal Width	26.70	26.30

5 Dimensions

Table 1 specifies the required dimensions of the EM CsI(Tl) crystals, taken from LAT-SS-00820. As we stated above, the dimensions were modified after the crystals were originally cut at the factory. Each crystal was therefore returned to the factory to have its length reduced to 326 mm, and then it was forwarded to Kalmar, where the chamfers were recut.

The height and width histograms represent 48 crystals from the second batch of 110 test crystals delivered in March 02 to Kalmar from Amcrys-H. Measurements are taken at six points along the length, and each of these measurements is included in the histograms. The length represents 63 crystals with both ends reworked without polishing after cutting the ends of the crystal. The individual values are from Amcrys measurements and are within ±0.02 mm of the values measured in Kalmar.

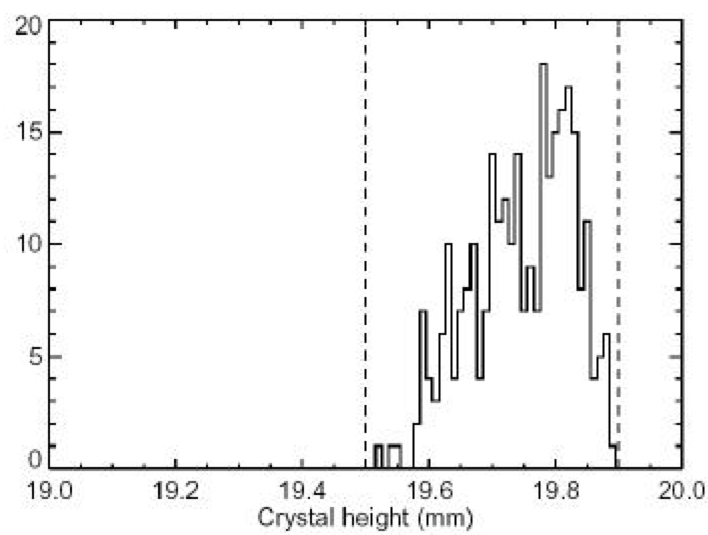

Figure 6: Distribution of EM crystal heights, as measured at Amcrys. Dashed lines indicate the height tolerance band.

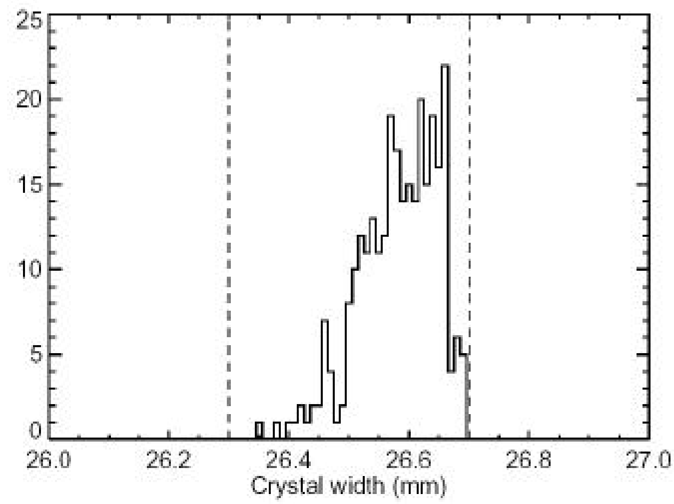

Figure 7: Distribution of EM crystal widths, as measured at Amcrys. Dashed lines indicate the width tolerance band.

For FM crystal production, Amcrys intends to choose target dimensions in the center of the tolerance band, to avoid the asymmetric distributions shown in, e.g., the EM width histogram. In the EM crystal build, fewer tunings of light taper were needed to achieve the specification than Amcrys expected, and therefore less crystal material was removed from the width than Amcrys anticipated. With the knowledge, Amcrys intends to cut the FM crystals to a target width 0.1 mm less than the EM crystals. Such statistics are always calculated by Amcrys during the manufacturing process to set the rough-cut dimensions. The height can be set by 0.1 mm steps or smaller, and the width and length can be set by 0.04 mm steps or smaller. Kalmar verified these dimensions with the EM crystals. After the initial batch of 110 crystals proved to be near the maximum tolerance, an established line of communication between Kalmar and Amcrys allowed the second batch of 110 crystals to be machined closer to the center of tolerance. We expect that such

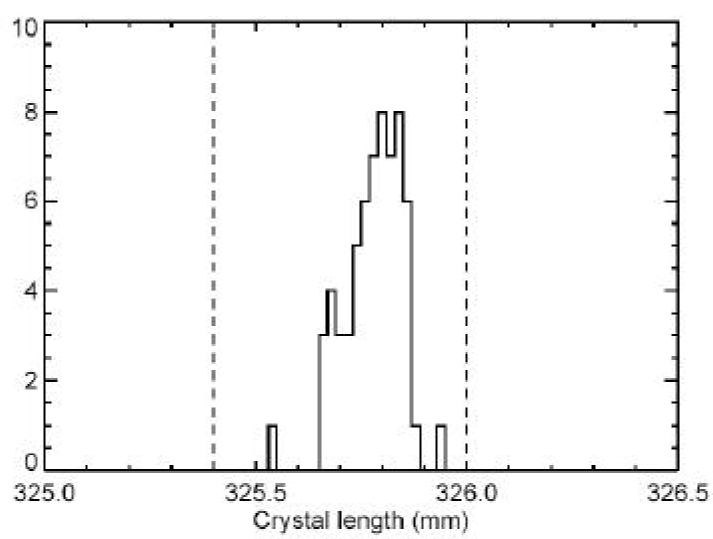

Figure 8: Histogram of crystal lengths. Measurements were made at Amcrys after cutting to revised EM length. Dashed lines indicate length requirement.

monitoring and communication will allow us to control any variation in production machinery between the various FM batches.

6 Conclusion

Blah blah some concluding paragraph.